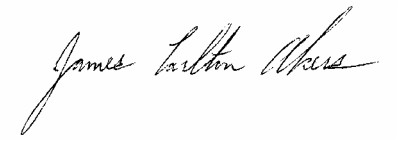
Multi-User Droplet Combustion Apparatus (MDCA)

Acoustic Emissions Verification Test Report

June 2004

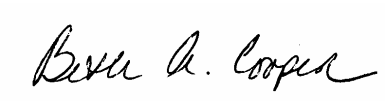
Prepared by:



7/19/04

Analex/James Akers, Ph.D. Date
ATL Test Engineer

Approved by:



7/19/04

7735/Beth Cooper Date
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Acoustical Testing Laboratory

TEST REPORT

Glenn Research Center
Engineering & Technical Services Directorate
7735/Structural Systems Dynamics Branch

Multi-User Droplet Combustion Apparatus (MDCA)

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ACOUSTICAL TESTING LABORATORY

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1. Introduction.

This document will serve as the test report for acoustic emissions verification testing of the Multi-User Droplet Combustion Apparatus (MDCA). The MDCA test article was comprised of a flight hardware Chamber Insert Assembly (CIA) and a flight hardware Avionics Package (AP). These test articles will be referred to as the MDCA CIA and MDCA AP, respectively, in this document. The MDCA CIA resides inside the combustion chamber of the Fluids and Combustion Facility (FCF) Combustion Integrated Rack (CIR). The MDCA AP mounts to the front of the CIR Experiment Assembly (i.e. the CIR optics bench).

The purpose of this test was to measure the acoustic emission levels of MDCA for purposes of comparison with the limits specified in FCF-ICD-CIR-MDCA Rev B for both continuous and intermittent acoustical noise of payloads both inside the combustion chamber (MDCA CIA) and outside the combustion chamber (MDCA AP).

During this test, 60 second Leq averaged one-third octave band sound pressure level data and 60 second Leq averaged overall A-weighted sound levels were acquired. The one-third octave band sound pressure level data were post processed into equivalent octave band sound pressure level data. In addition, the maximum slow exponential, fast exponential, and impulsive overall A-weighted sound level data were acquired to help characterize the non-stationary (i.e. transient, impulsive, etc) noise characteristics exhibited by MDCA.

1.1. Applicable Documents

Multi-User Droplet Combustion Apparatus Interface Control Document, FCF-ICD-CIR-MDCA Rev B: December 2003.

4.10.1.2.1	Continuous Noise Limits
4.10.1.2.2	Intermittent Noise Limits
4.10.1.2.3	Continuous Noise Sources with Intermittent Nose Features

Multi-User Droplet Combustion Apparatus Payload Verification Plan, FCF-PVP-CIR-MDCA Rev A: January 2004.

B-153	Continuous Noise Limits
B-154	Intermittent Noise Limits
B-155	Continuous Noise Sources with Intermittent Nose Features

1.2. Summary of Test Results

The MDCA AP meets the FCF-ICD-CIR-MDCA Rev B Continuous Noise Limits for payloads inside or outside the combustion chamber. An aural survey of the MDCA AP showed that it is not an acoustic noise source.

The MDCA CIA meets the FCF-ICD-CIR-MDCA Rev B Continuous Noise Limits for payloads inside the combustion chamber. The MDCA CIA was tested with a single test condition. This test condition consisted of the normal operating cycle (duration of approximately 10 seconds) continuously repeating. This normal operating cycle of the MDCA CIA was composed of several different short period transients and impulses. The loudest (highest overall A-weighted sound level) location was behind the MDCA CIA (back microphone position), with an A-weighted sound level 53 dBA (50 Hz – 10 kHz). Table 1 lists the sound pressure levels on each side of the MDCA CIA with the highest A-weighted sound levels. Figure 1 and Figure 2 show these sound pressure levels with the Continuous Noise Limits for payloads inside the combustion chamber.

A detailed discussion of the test results and noise requirements is given in Section 6 and Section 7.

Table 1. Sound pressure levels on each side of the MDCA CIA with highest A-wtd sound levels from all test runs and the Continuous Noise Limits for payloads inside the combustion chamber.

Continuous Noise Limits Inside Combustion Chamber

Octave Frequency (Hz)	Limit SPL (dB)	Top SPL (dB)	Front SPL (dB)	Right SPL (dB)	Back SPL (dB)	Left SPL (dB)	Bottom SPL (dB)
63	57	40	35	37	**39**	38	40
125	51	23	25	25	**25**	24	23
250	60	30	29	29	**29**	29	29
500	60	42	39	38	**40**	40	44
1000	60	46	47	47	**48**	46	48
2000	58	45	44	45	**46**	45	46
4000	57	45	44	45	**47**	45	44
8000	56	37	38	37	**37**	36	36
A-Weighted		52	51	52	**53**	51	53
Linear		52	51	51	**53**	51	53

= Highest A-wtd sound level of all test runs.

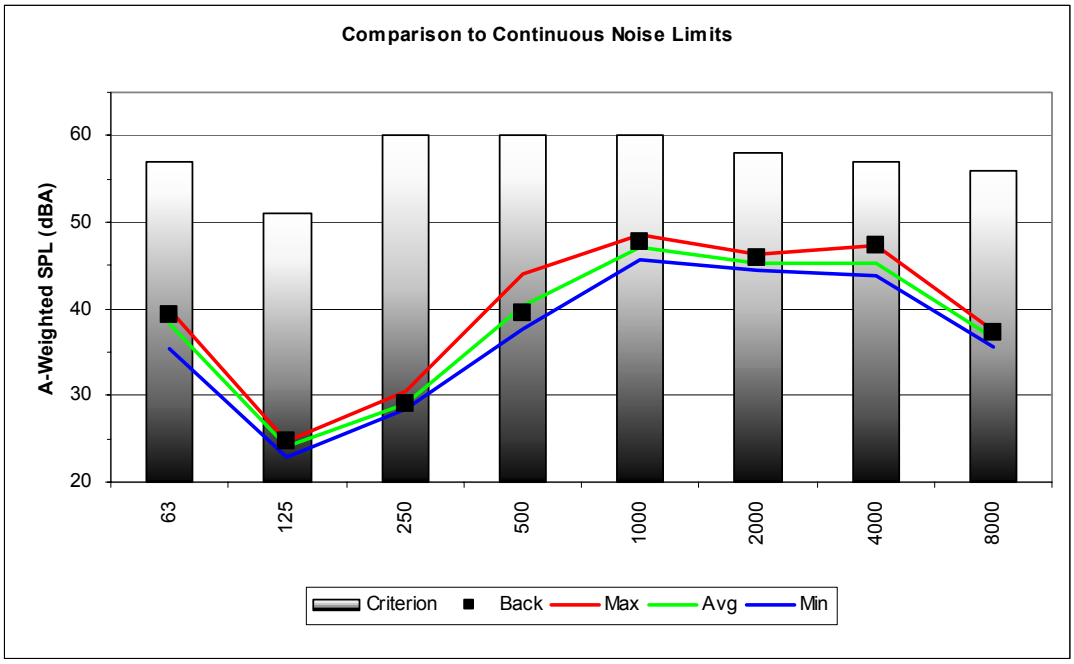

Figure 1. Sound pressure level at the microphone position (back) with the highest A-wtd sound level of all test runs (highlighted in green in Table 1).

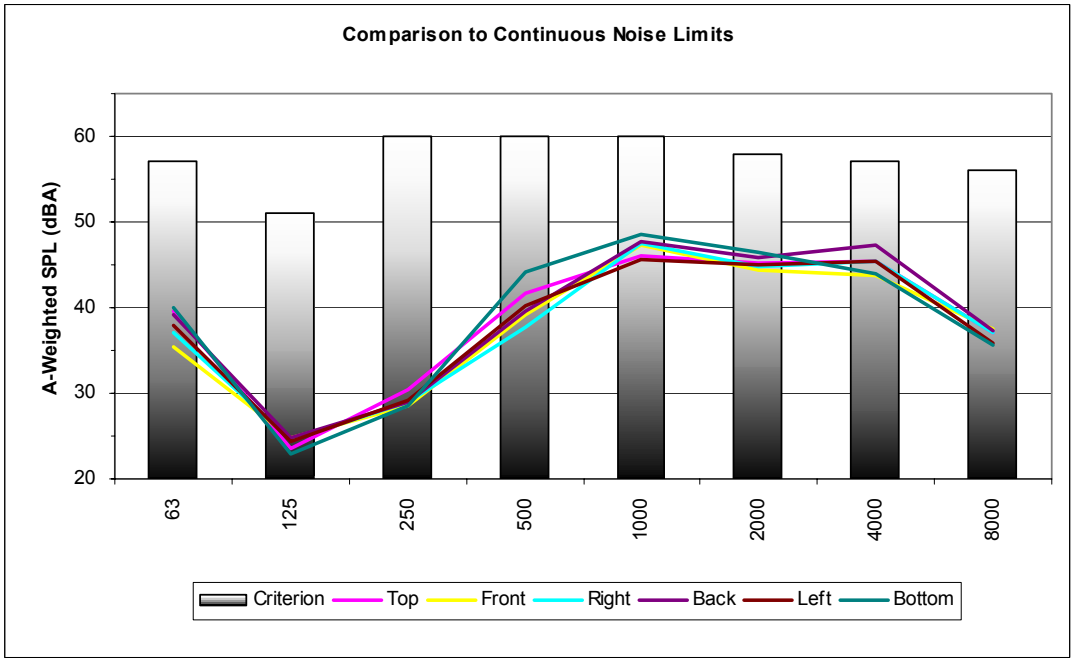

Figure 2. Sound pressure levels with the highest A-wtd sound levels from all test runs on each side compared with the Continuous Noise Limits for payloads inside the combustion chamber..

2. Customer Contacts

Table 2 lists the customer contacts for the MDCA acoustic emissions test . Joel Knapp was present during all acoustic emissions testing. Other MDCA personnel present during part or all of the test were Peter Galant, Mike Garret, Arthur Disantis, Wendell Booth and Joe Intorre. Brian Loucks, Zin Technology was the Quality Assurance person for this test.

Table 2. MDCA Customer contact list.

Person	Title	Phone Number
Craig Myhre	GRC MDCA Project Manager	(216) 433-8741
Brian Borowski	MRDOC MDCA Project Manager	(216) 925-1192
Joel Knapp	MDCA Systems Lead	(216) 925-1060

3. Test Schedule.

Testing took place in the NASA Glenn Research Center (GRC) Acoustical Testing Laboratory (ATL), located inside of Bldg. 333 Annex. The Customer arrived Monday morning, June 7, 2004, with the MDCA AP and MDCA CIA and support equipment. The Customer installed the MDCA AP in the ATL test chamber and their power supplies and support computer in the ATL control room. Testing began at 10:15 am with an aural survey of the MDCA AP. Testing of the MDCA CIA followed and was completed by 4:15 pm.

Preliminary analysis of the test data was performed late Monday evening and early Tuesday morning. Tuesday morning the GRC photo lab took pictures of the MDCA CIA test article in the test chamber, Customer personnel, and ATL personnel involved with the test. At the conclusion of picture taking all MDCA hardware and support equipment were removed from the test chamber and control room. The Customer left ATL by 10:00 am Tuesday morning.

4. MDCA Test.

4.1. Test Article Description

The MDCA test article was comprised of a flight hardware MDCA AP and a flight hardware MDCA CIA. The MDCA AP provides the processing and control interface hardware for controlling the MDCA CIA and communicating with the CIR hardware. The MDCA AP controls the MDCA CIA motors, provides the functions for input and output data control, and is the source for experimental data collection. The MDCA AP receives 28 VDC from the CIR. The MDCA AP is a rectangular box

with overall dimensions of 28 cm (11 inches) wide x 33 cm (13 inches) tall x 25 cm (10 inches) deep.

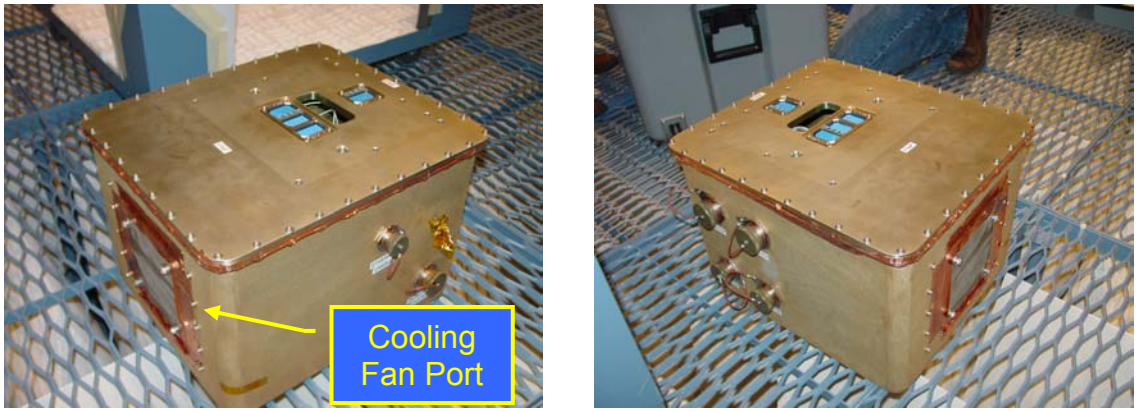

Figure 3. Two views of the optics bench simulator (OBS) without the MDCA Avionics Package (AP) installed.

For purposes of testing, the MDCA AP was mounted to an Optics Bench Simulator (OBS), which simulates the cooling, electrical power, and data interface provided by the CIR the optics bench. The OBS is a rectangular box with overall dimensions of 41 cm (16 inches) wide x 33 cm (13 inches) tall x 46 cm (18 inches) deep. The OBS has a single cooling fan on one side, which draws air into the OBS and blows it out through the MDCA AP. Figure 3 shows the OBS by itself. Figure 4 and Figure 5 show the MDCA AP mounted to the OBS during buildup in Building 333 high bay. The MDCA AP and OBS weigh less than 45 kg (100 lb).

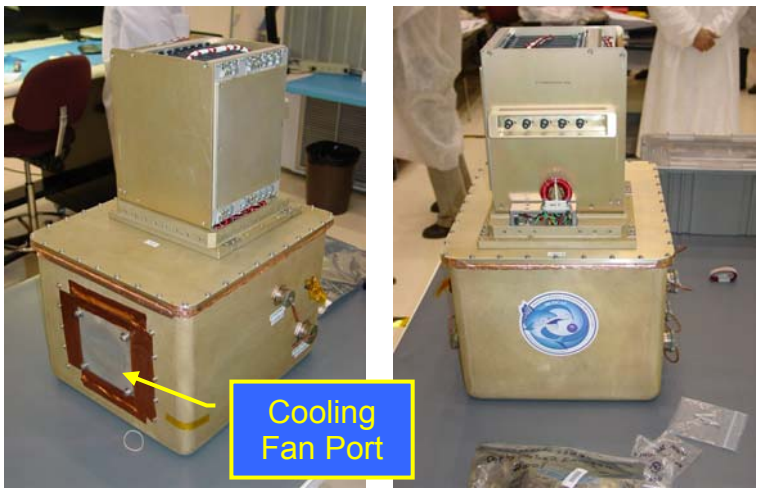

Figure 4. Two views of the MDCA CIA mounted to an OBS during buildup in Building 333 high bay.

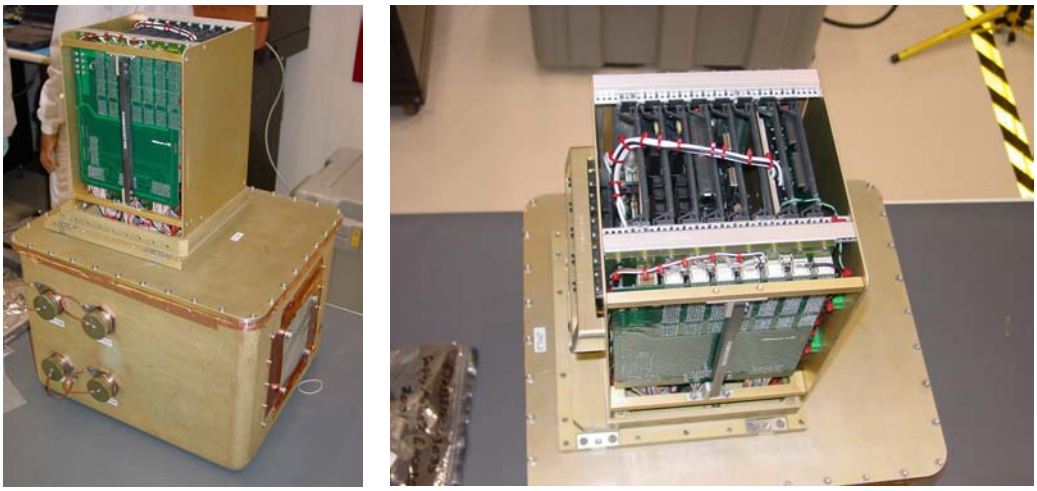

Figure 5. Two more views of the MDCA CIA mounted to an OBS during buildup in Building 333 high bay.

The MDCA CIA is cylindrical with a diameter of approximately 9.9 cm (14 inches) and an overall length of 66 cm (26 inches). The MDCA CIA was supported with a cradle fixture having rollers that allow the MDCA CIA to be rotated about its longitudinal axis. The MDCA CIA and cradle fixture weigh less than 45 kg (100lb). Figure 6 through Figure 9 show the Dispensing System, Droplet Deployment System, Retractable Indexing Fiber mechanism, and the Ignition System in the MDCA CIA Functional Unit (FU). The MDCA CIA was not fueled during this test and therefore no combustion took place during this test.

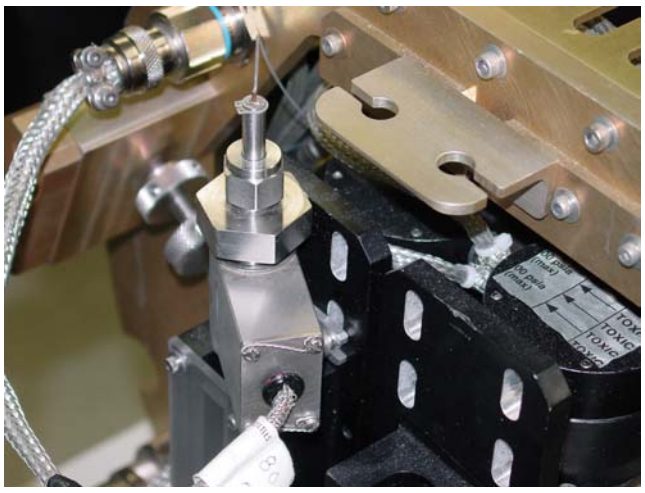

Figure 6. Close up view of the Dispensing System in the MDCA CIA Functional Unit (FU).

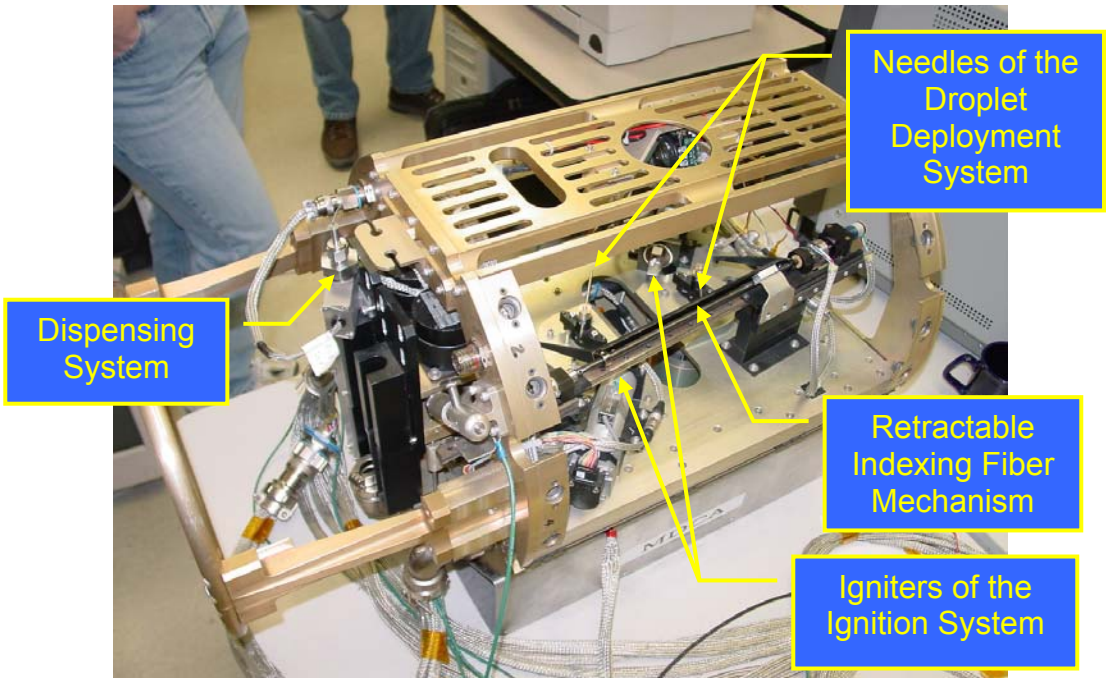

Figure 7. MDCA CIA FU.

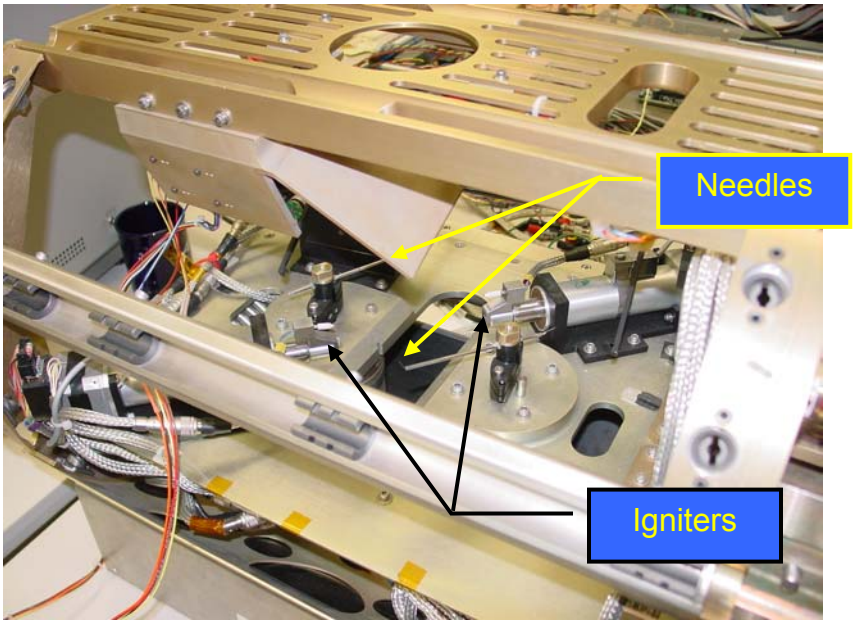

Figure 8. Close up of the needles of the Droplet Deployment System and the igniters of the Ignition System in the MDCA CIA FU.

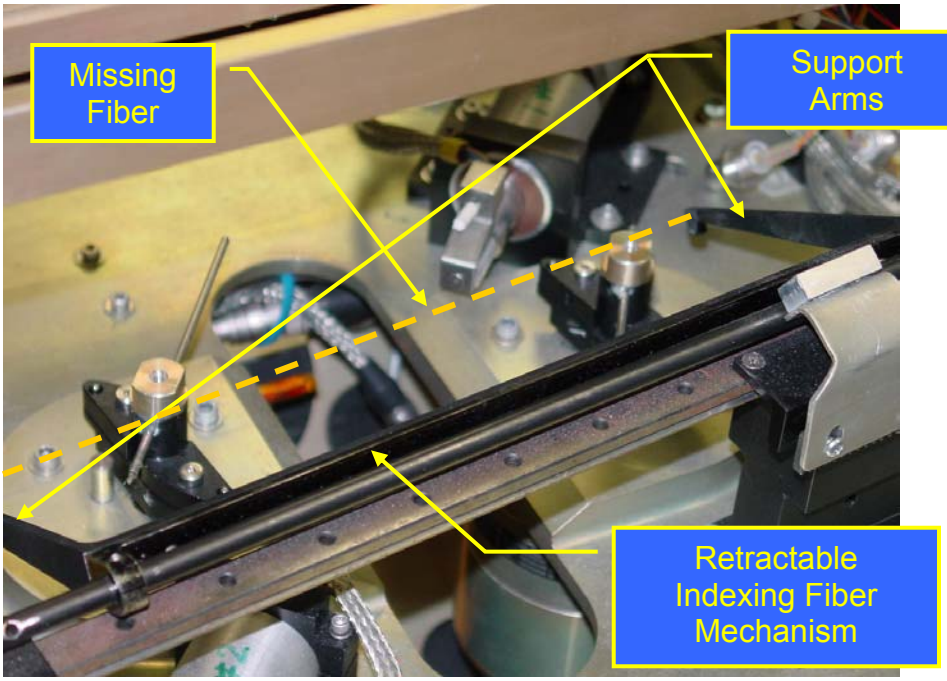

Figure 9. Close up view of the Retractable Indexing Fiber mechanism in the MDCA CIA FU. (Note that the fiber that runs between the two support arms is not present in this photo.)

4.2. Test Facilities and Equipment

The acoustic emissions testing of the MDCA was performed at the NASA GRC ATL. The ATL test chamber was configured in its fully anechoic mode with the grating floor installed. The ATL test chamber HVAC and the control room HVAC were off during all testing. The Bldg 333 Annex HVAC was on during all testing. The relative humidity level inside the test chamber was between 30% and 50% throughout the test. Since the test chamber HVAC draws its air in from the air inside of Bldg 333 Annex and the relative humidity inside Bldg 333 Annex was between 35% and 40%, additional humidification/dehumidification of the test chamber was not needed.

4.3. Test Support Requirements

The Customer supplied two power supplies for their 24 VDC and 28 VDC power needs, a support computer, and all MDCA power and data cables. The power supplies and support computer were located in the control room and were run off the 120 V AC outlets located in the ATL control room. The Customer's support equipment is shown in Figure 10

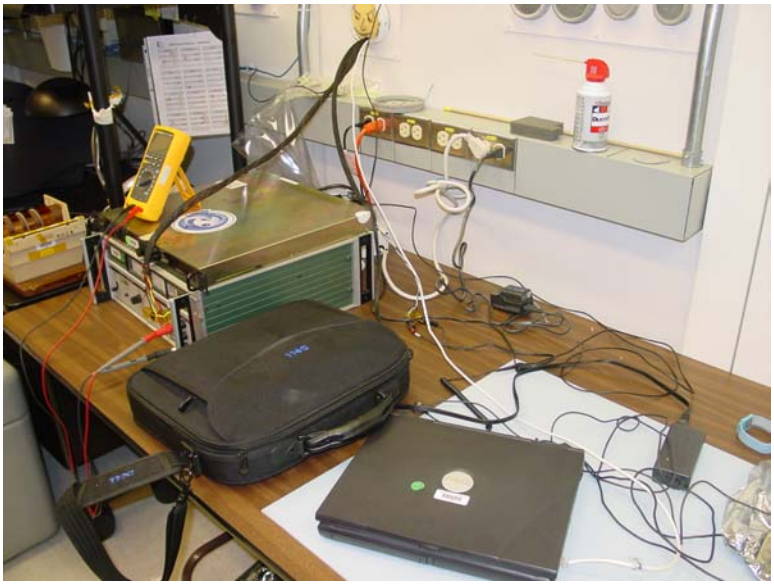

Figure 10. MDCA power supplies and support computer located inside the ATL control room.

4.4. Test Setup

All data acquisition and support equipment were located in the ATL control room adjacent to the test chamber. The MDCA power and data cables were passed through a utility penetration port that feeds into the East side of the test chamber. All personnel were in the control room during data acquisition.

One of the 3-foot by 3-foot wedge carts that normally fills in next to the large double doors was removed and used as a test fixture to support the MDCA AP and MDCA CIA. The wedges from this wedge cart were removed and used to fill in the spot left empty by the removal of the wedge cart. This wedge cart was placed up on the main grating floor at the center of the test chamber. Four 2-foot extension posts were used to elevate the grating floor section so that it was 1.57 meters (62 inches) above the main grating floor. Acoustical absorptive foam was used on the base of the wedge cart to reduce any acoustical reflections off the cart's structural members.

The MDCA AP and OBS were hand carried into the ATL test chamber by the Customer. The MDCA AP had the astronaut-handling adapter attached. The MDCA AP mounted to the OBS was then placed on top of the modified wedge cart with small pieces of foam under it to prevent it from rattling on the elevated grating floor section. Figure 11 shows the MDCA AP mounted to the OBS on top of the modified wedge cart.

Because the OBS fan is a significant noise source it was turned off during all testing of the MDCA AP and MDCA CIA. However, the MDCA AP was not allowed to operate for more than 90 seconds without the OBS fan running in order to avoid over heating.

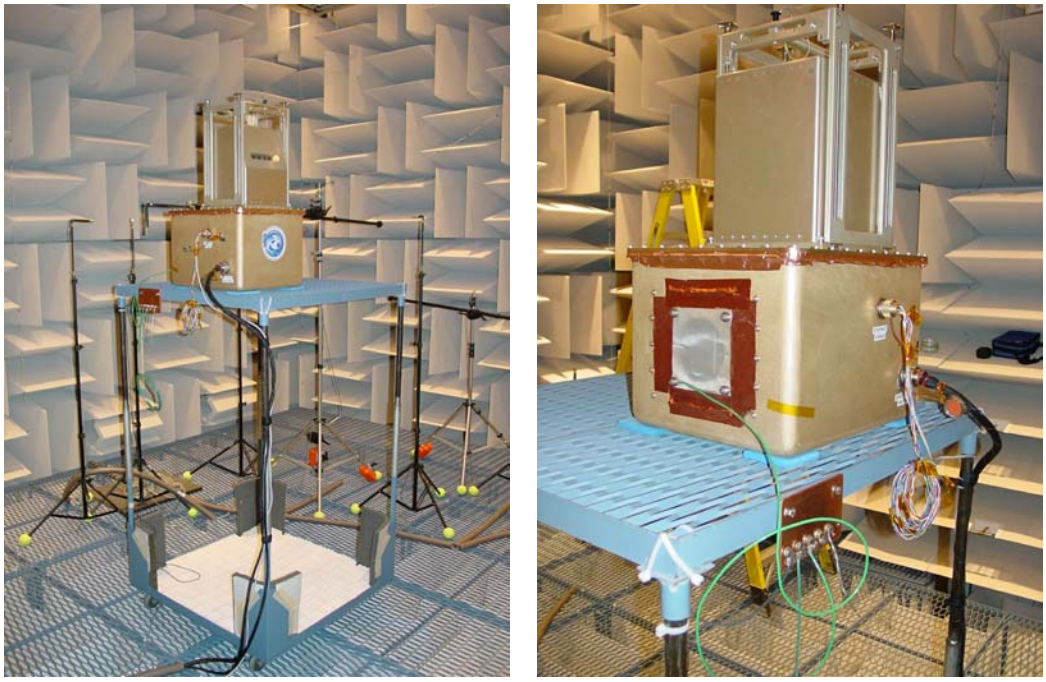

Figure 11. MDCA AP mounted to the OBS installed on top of modified wedge cart.

After the aural survey of the MDCA AP had been completed (with the OBS fan turned off), the MDCA AP mounted to the OBS was placed down on a large foam pad on the main grating floor in the Southeast corner of the ATL test chamber during MDCA CIA testing. During data acquisition when the MDCA CIA was being tested, the MDCA AP mounted to the OBS was covered with melamine foam panels and the OBS fan was turned off. The MDCA AP mounted to the OBS was more than 8 foot horizontally away from the MDCA CIA. Figure 12 and Figure 13 show the MDCA AP uncovered and covered, respectively.

Because of concerns of putting the MDCA CIA on top of the modified wedge cart, the 2-foot extension posts were removed from it, resulting in its elevated section of grating floor being lowered to 38 inches above the main grating floor. The MDCA CIA cradle fixture was hand carried into the ATL test chamber and installed on top of the modified wedge cart. Small pieces of foam were placed under it to prevent it from rattling on the elevated section of grating floor. The MDCA CIA was hand carried into the ATL test chamber and placed into the cradle. Because the

cradle fixture partially blocked the under side of the MDCA CIA, after measurements were taken with it right side up the MDCA CIA was rolled 180 degrees about is longitudinal axis (i.e. inverted) and measurements were retaken. Figure 14 shows the MDCA CIA both right side up and inverted.

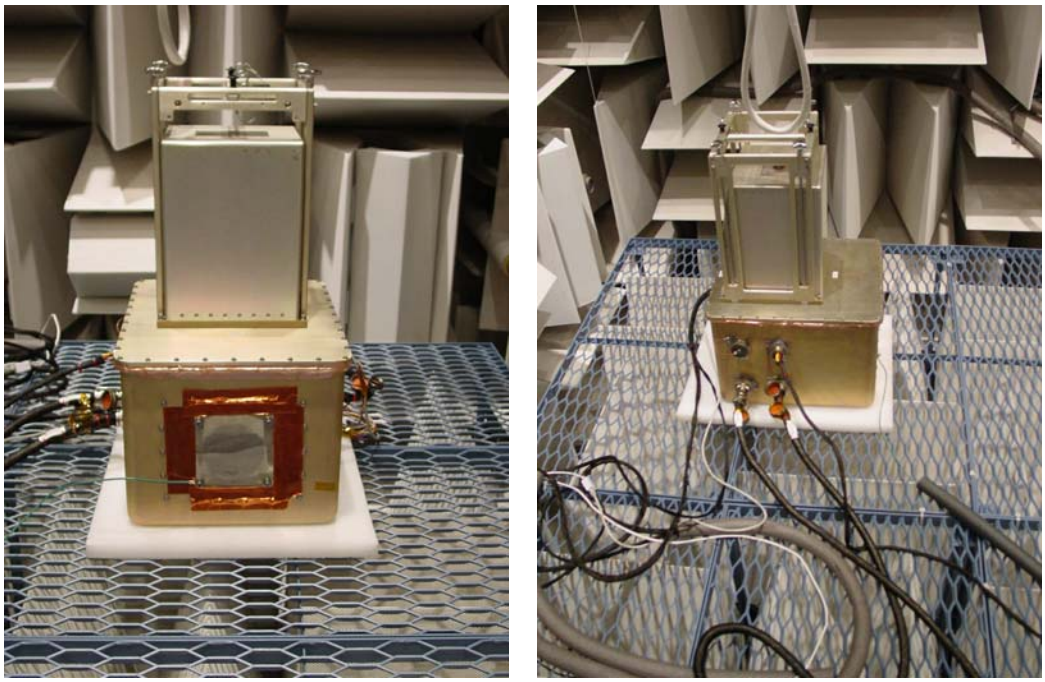

Figure 12. Two views of the MDCA AP mounted to the OBS in the Southeast corner of the test chamber (uncovered).

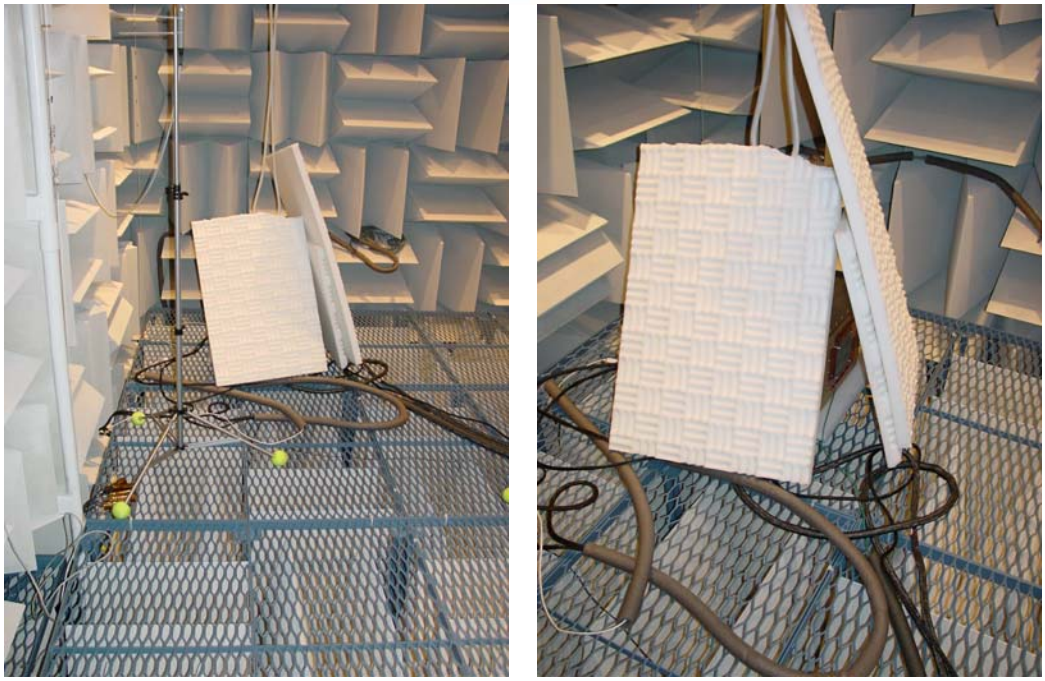

Figure 13. Two views of the MDCA AP mounted to the OBS in the Southeast corner of the test chamber (covered).

Figure 14. Close up view of the MDCA CIA installed on top of the modified wedge cart in the ATL test chamber. Right side up (l) and inverted (r).

All setup and testing of the MDCA was performed on Monday, June 7, 2004. Teardown and removal of the MDCA test article was done on Tuesday morning, June 8, 2004.

4.5. Microphone Locations

A six (6) position microphone array was used to measure the sound pressure levels on all six sides of the MDCA CIA test article. A hand held sound level meter survey was first performed with a Quest 1400 Sound Level Meter using a slow exponential time weighting filter in order to determine the loudest (highest overall A-weighted sound level) location on each side of the MDCA CIA. A spacing rod with a soft rubber tip covered in Kapton tape was attached to the Quest 1400 to maintain the 0.6 meter stand off distance. This hand held survey was not able to identify the loudest locations due to the nonstationarity of the MDCA CIA acoustic noise sources. Therefore, the microphones on the sides, top, and bottom were positioned 0.6 meters out from the center of the large holes in the housing of the MDCA CIA. These holes were just slightly aft of the geometric center of the test article. The longitudinal centerline of the MDCA CIA test article was 51 inches above the main grating floor.

Microphone position #1 was located 0.6 meters above, microphone position #2 was located 0.6 meters in front microphone position #3 was located 0.6 meters from the right side, microphone position #4 was located 0.6 meters from back side, microphone position #5 was located 0.6 meters from the left side, and microphone position #6 was located 0.6 meters beneath the under side. Microphone positions #2 - #5 were 51 inches above the main grating floor. Figure 15 and Figure 16 show these microphone positions. The same microphone positions were used when the MDCA CIA was both right side up and inverted.

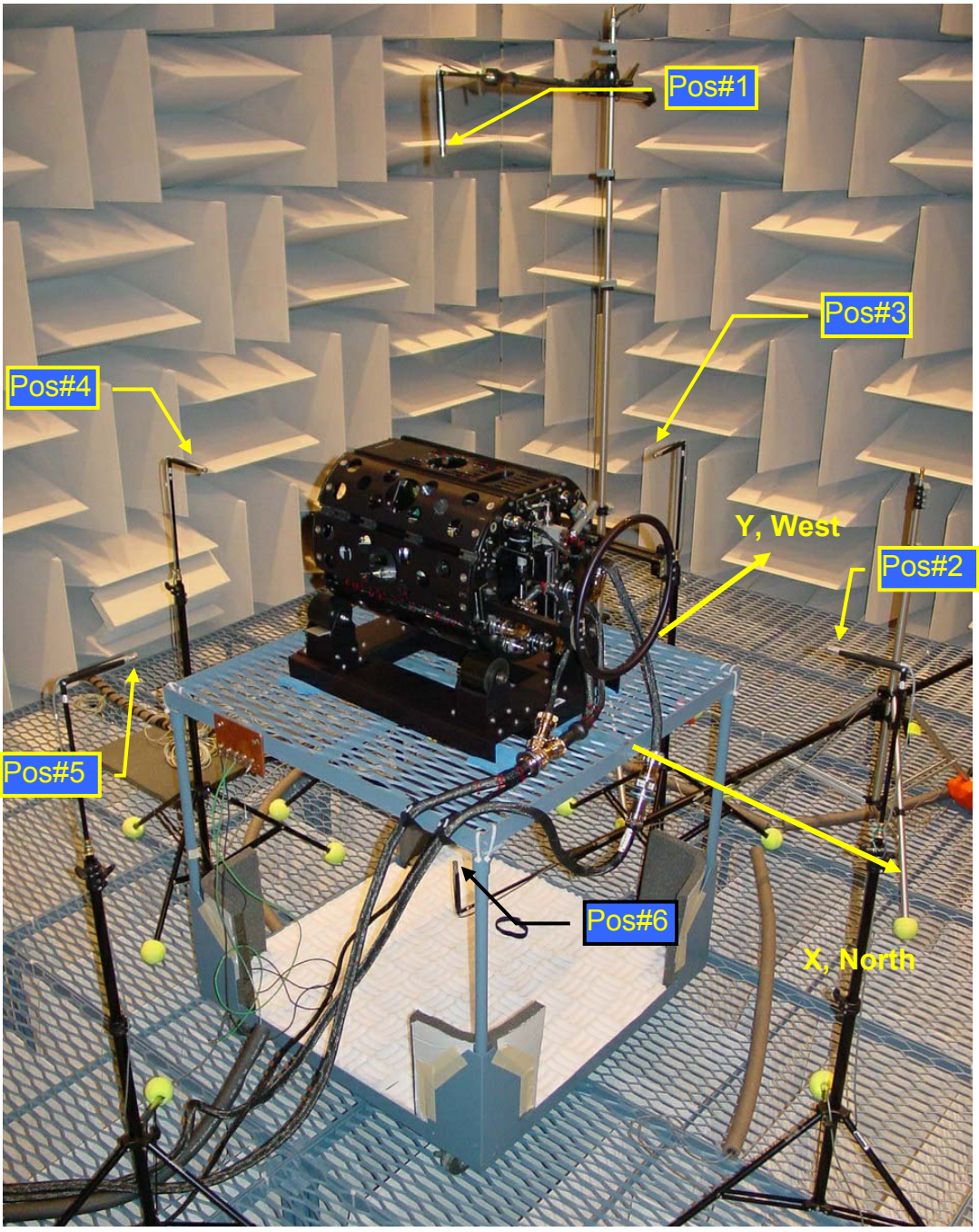

Figure 15. Left front corner of MDCA CIA test article with microphone array.

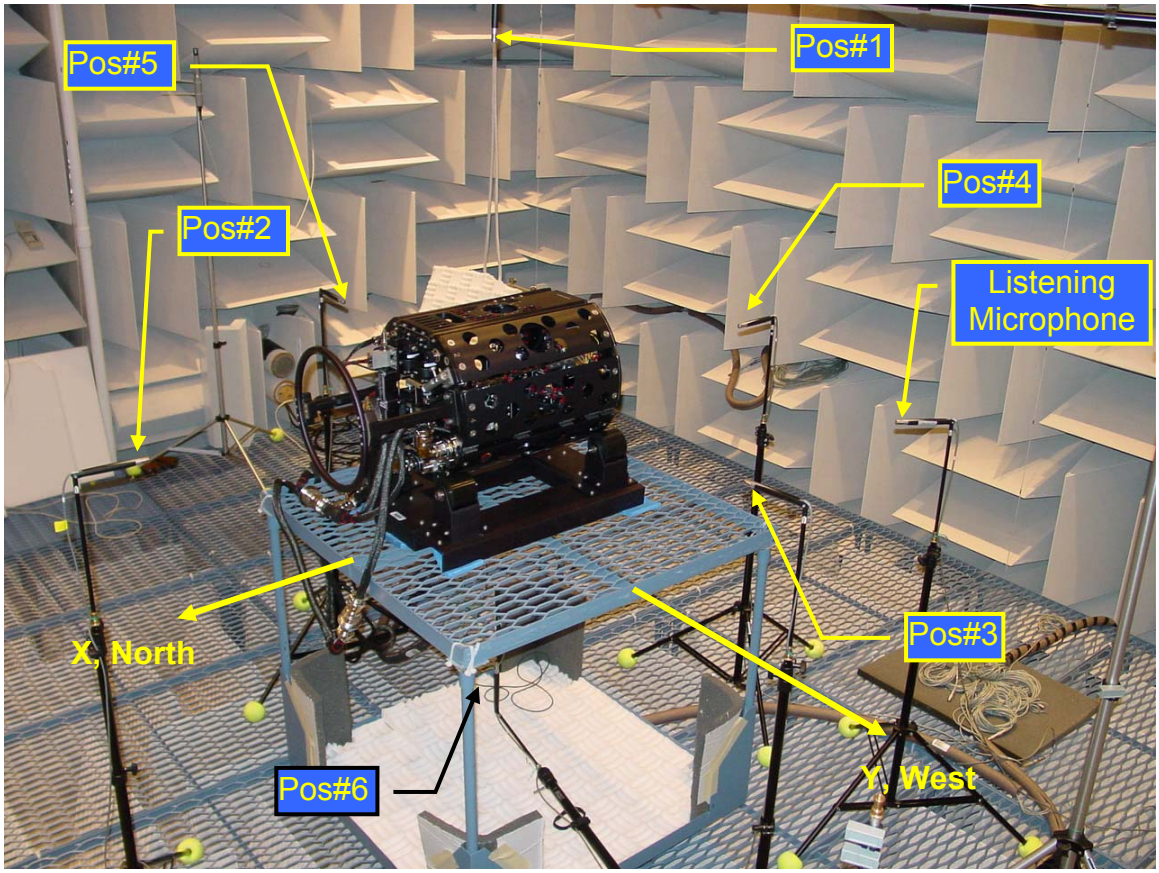

Figure 16. Right front corner of the MDCA CIA test article with microphone layout.

All microphones were supported with tripod stands and booms and faced toward the test article. Windscreens were not used on any of the microphones.

In addition to these six microphones, two additional microphones were set up. One microphone was positioned inside the ATL test chamber at the back right corner for listening purposes. A second microphone, located on the roof of the ATL control room, was used for noise intrusion monitoring. Neither of these microphones was used to acquire sound pressure level data on the MDCA CIA.

Prior to the start of testing for the day, all microphones were calibrated with a pistonphone calibrator. All ATL instrumentation and the data acquisition system were in calibration and meet the instrumentation requirements of SSP 57000.

4.6. Test Conditions

The MDCA AP test article was tested in one operating condition, being powered on. The MDCA CIA test article was tested with its normal operating condition (duration of approximately 10 seconds) continuously repeating.

5. Data Acquisition.

For each operating condition, seven channels of one-third octave band (50 Hz – 10 kHz) sound pressure level spectra were acquired simultaneously, using the ATL National Instruments™ (NI) data acquisition system (customized Sound Power System software with Multi-Channel Extension software). Six channels measured sound pressure levels of the test article at the six microphone locations discussed in Section 4.5. The seventh channel recorded the predicted sound pressure level (noise intrusion level) inside the ATL test chamber due to the sound pressure levels in the host building (i.e. Bldg 333 Annex). This predicted sound pressure level was calculated by measuring the sound pressure level inside the host building at the reference microphone located on top of the ATL control room and subtracting the noise reduction correction, which relates the sound pressure level at the reference microphone location to the average sound pressure level inside the ATL test chamber. This noise reduction correction is the sound attenuation produced by the walls of the ATL test chamber and was determined during the ATL Chamber Qualification Tests in June 2001.

Ambient (background) sound pressure level spectra were measured (60 second Leq averaged) at each microphone prior to acquiring the measured source sound pressure levels for the first and fourth (first test run with the MDCA inverted) test runs. Figure 17 and Figure 18 show the ambient (background) sound pressure level spectrum at each microphone position from the first test run compared to the FCF-ICD-CIR-MDCA Rev B Continuous Noise Limits and the Intermittent Noise Limits, respectively. The maximum ambient (background) A-weighted sound level inside the ATL test chamber was 19 dBA (50 Hz – 10 kHz).

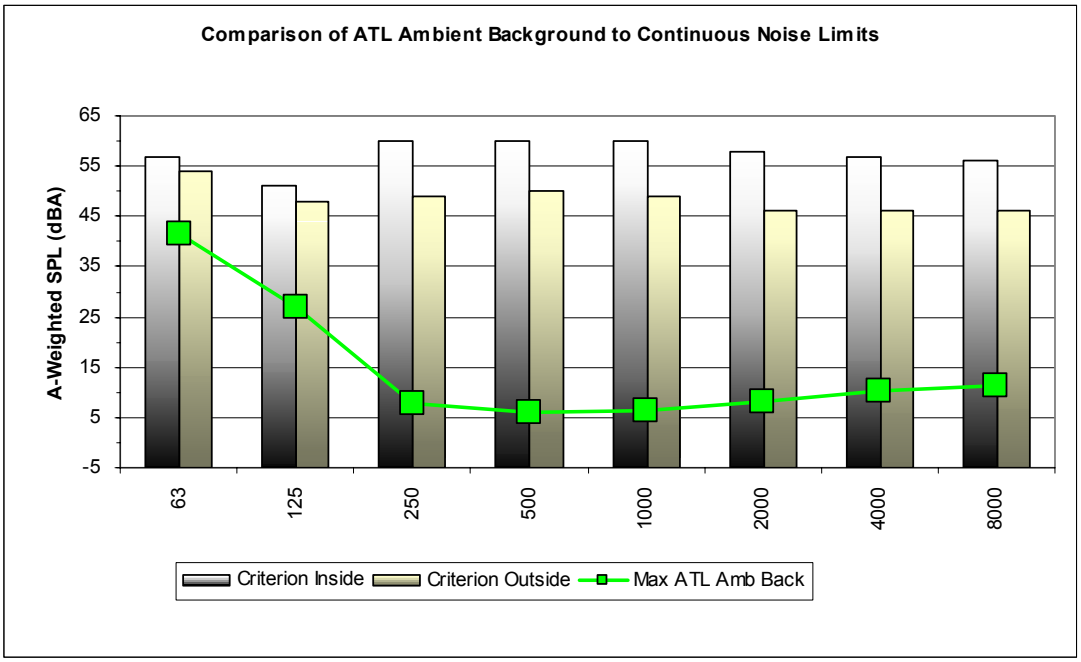

Figure 17. Ambient (background) sound pressure level spectra at each microphone position from the first test run vs the Continuous Noise Limits for payloads inside and outside the combustion chamber.

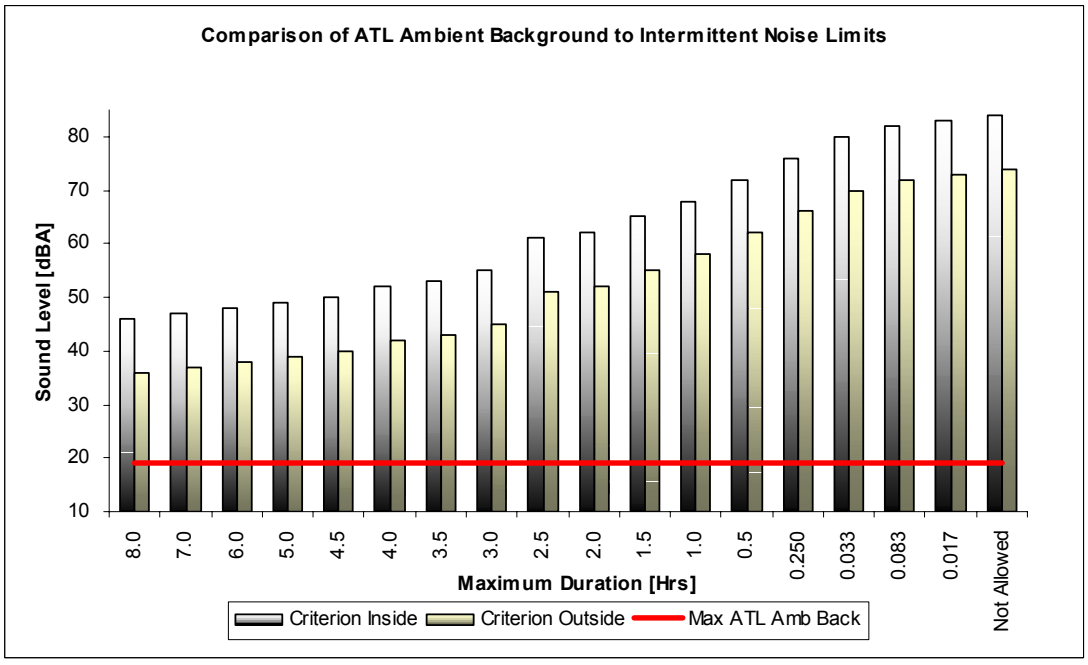

Figure 18. Ambient (background) A-wtd sound level at each microphone position from the first test run vs the Intermittent Noise Limits for payloads inside and outside the combustion chamber.

These one-third octave band data are automatically output by the NI data acquisition software to multi-sheet Excel workbooks that converted the one-third octave band data into equivalent octave band data. These workbooks also include a description of the test configuration.

The ambient sound pressure level correction limit was 6 dB, position by position (apply correction below limit). This means that if measured source sound pressure level at an individual microphone position was less than 6 dB above the ambient (background) sound pressure level then the measured corrected source sound pressure level is given by:

$$\text{Corrected Source SPL} = \text{Measured Source SPL (dB)} - 1.3\,\text{dB}.$$

If the measured source sound pressure level at an individual microphone position was greater than 6 dB above the ambient (background) sound pressure level then the measured corrected source sound pressure level is given by:

$$\text{Corrected Source SPL} = 10 * \log 10\,[10\text{^}(\text{Measured Source SPL}/10) - 10\text{^}(\text{Ambient SPL}/10)]$$

This ambient (background) correction of the measured source sound pressure level is shown in Figure 19.

In addition to the Leq averaged sound pressure level data acquired by the NI data acquisition system, a Larson Davis (LD) 2900B real-time analyzer was used to independently acquire the maximum slow exponential, fast exponential, and impulsive overall A-weighted sound levels. These overall A-weighted sound levels have not (and cannot be) corrected for the ambient (background) sound pressure levels. However, since the maximum ambient (background) overall A-weighted sound levels inside the chamber was 19 dBA (50 Hz – 10 kHz), the effect of the ambient background sound pressure levels on the peak slow exponential, fast exponential, and impulsive overall A-weighted sound levels is not significant.

Table 6 lists the channel configuration. Table 5 lists the test run log contained in ATL TRL-09-04.xls. All test data were backed up onto a CD prior to breaking for lunch and at the conclusion of the day's testing to prevent the accidental loss of data.

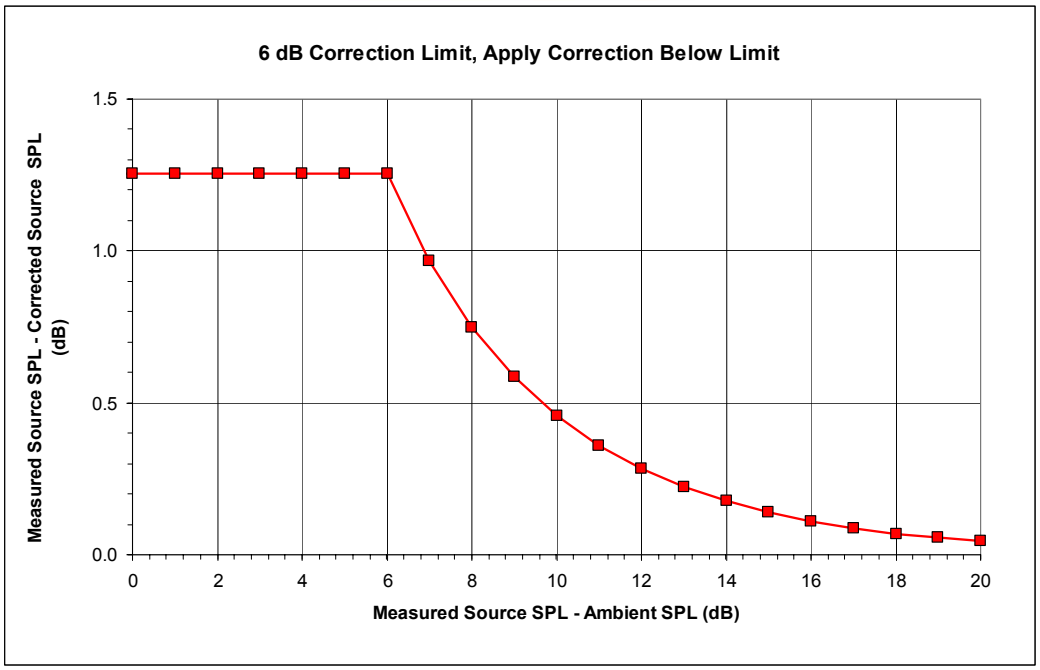

Figure 19. Ambient (background) correction.

6. FCF-ICD-CIR-MDCA, Rev B Continuous and Intermittent Noise Limits.

Paragraphs 4.10.1.2.1 through 4.10.1.2.3 of FCF-ICD-CIR-MDCA Rev B specify the acoustical noise limits for MDCA. Pages B-153 through B-155 of FCF-PVP-CIR-MDCA Rev A specifies how to perform an acoustic emissions verification test. Table 3 and Table 4 list the acoustic limits specified in FCF-ICD-CIR-MDCA Rev B for both continuous and intermittent acoustical noise, respectively.

Our understanding of the acoustic noise requirements specified in FCF-ICD-CIR-MDCA Rev B is that an acoustic emissions verification test shall be performed with a measurement surface that is 0.6 meters from the sides of the test article. The best effort shall be made to place microphones at the loudest (highest overall A-weighted sound level) location on each side of this measurement surface to measure the sound pressure levels. The selection of microphone locations shall be based upon the geometry of the primary noise sources, an aural survey, and a hand held sound level meter survey of the test article. Sound pressure levels shall be acquired using Leq averaging with a minimum acquisition duration of 60 seconds. The acquisition duration shall be sufficiently long enough so that the Leq average is calculated over several operating cycles. The sound pressure level shall be measured in the eight octave bands: 63 Hz, 125 Hz, 250 Hz, 500 Hz, 1 kHz, 2 kHz, 4 kHz, and

8 kHz. Also the overall Leq averaged A-weighted sound level (dBA, 50 Hz – 10 kHz) shall be measured. In addition, for operating conditions that exhibit nonstationary acoustic noise (i.e. transients, chirps, impulses) the max slow exponential, fast exponential, and impulsive overall A-weighted sound levels should be measured and reported for informational purposes.

Table 3. FCF-ICD-CIR-MDCA Rev B Continuous Noise Limits.

Octave Band Center Frequency (Hz)	Total Rack Based on NC-40 (dB)	Payload Within Combustion Chamber (dB)	Payload Outside Combustion Chamber (dB)*
63	64	57	54
125	56	51	48
250	50	60	49
500	45	60	50
1000	41	60	49
2000	39	58	46
4000	38	57	46
8000	37	56	46

Note: (*) Includes the CIR configurable hardware.

A payload is considered to meet the Continuous Noise Limits when the sound pressure level spectrum at the loudest (highest overall A-weighted sound level) microphone location does not exceed the levels specified in Table 3. A payload is considered to meet the Intermittent Noise Limits when the overall A-weighted sound level (Leq averaged) at the loudest (highest overall A-weighted sound level) microphone location does not exceed the levels specified in Table 4. If a payload meets the Continuous Noise Limits, then it is not required to meet the Intermittent Noise Limits.

Table 4. FCF-ICD-CIR-MDCA Rev B Intermittent Noise Limits.

Time NC-40 is Exceeded During a 24-Hour Period (1)	Total Rack A-Weighted Sound Level (2) (dBA)	Payload Within Combustion Chamber A-Weighted Sound Level (dBA)	Payload Outside Combustion Chamber A-Weighted Sound Level (3) (dBA)
8 Hours	49	46	36
7 Hours	50	47	37
6 Hours	51	48	38
5 Hours	52	49	39
4.5 Hours	53	50	40
4 Hours	54	52	42
3.5 Hours	55	53	43
3 Hours	57	55	45
2.5 Hours	58	61	51
2 Hours	60	62	52
1.5 Hours	62	65	55
1 Hour	65	68	58
30 Minutes	69	72	62
15 Minutes	72	76	66
5 Minutes	76	80	70
2 Minutes	78	82	72
1 Minute	79	83	73
Not Allowed	80	84	74

Notes:

(1) If the noise from the payload were at the level in this table for the duration specified in this column, no other payload operation would be permitted during the remainder of the 24-hour period.

(2) A-weighted Sound Pressure Levels (SPL), dB referenced to 20 micropascals. Measured at 0.6 meters (1.97 foot) distance from the noisiest surface with equipment operating in the mode or condition that produces the maximum acoustic noise. Round dBA to the nearest whole number.

(3) Includes the payload components and CIR configurable components.

7. Test Results.

An aural survey of the MDCA AP showed that it is not an acoustic noise source and therefore meets the FCF-ICD-CIR-MDCA Rev B Continuous Noise Limits for payloads outside the combustion chamber.

The MDCA CIA meets the FCF-ICD-CIR-MDCA Rev B Continuous Noise Limits for payloads inside the combustion chamber. The MDCA CIA was tested six times with the same test condition. This test condition consisted of the normal operating cycle (duration of approximately 10 seconds) continuously repeating. This normal operating cycle of the MDCA CIA was composed of several different short period transients and impulses. This test condition had to be repeated due to the impulsive nature of the MDCA CIA acoustic noise sources causing the loudest location to vary from test run to test run.

The loudest (highest overall A-weighted sound level) location was behind the MDCA CIA (back microphone position), with an A-weighted sound level 53 dBA (50 Hz – 10 kHz). Table 1 lists the sound pressure levels on each side of the MDCA CIA with the highest A-weighted sound levels. Figure 1 and Figure 2 show these sound pressure levels and the Continuous Noise Limits for payloads inside the combustion chamber.

Appendix A lists the measured corrected source sound pressure level spectra and overall A-weighted sound level at each microphone position for each test run with the MDCA CIA. These sound pressure level spectra are plotted against the FCF-ICD-CIR-MDCA Rev B Continuous Noise Limits, and the overall A-weighted sound levels are plotted against the FCF-ICD-CIR-MDCA Rev B Intermittent Noise Limits.

8. Data Reporting.

For each test run, one summary Excel workbook was synthesized from the associated unedited Excel workbooks (NI one-third octave band data). Each multi-sheet summary workbook contains all pertinent test data for that test run, including ambient sound pressure levels as well as uncorrected and corrected source sound pressure levels.

Along with these Excel workbooks is a single Excel workbook called **MDCA Summary Analysis.xls** that contains the measured corrected source octave band data for each test run and the peak slow exponential, fast exponential, and impulsive overall A-weighted sound levels measured with the LD 2900B real-time analyzer.

Digital photos were taken to document the testing process. A finalized set of digital photos has been placed in annotated PowerPoint files that are also included in the same parent folder with the test data. Two CD's will be created that each contain this test report, all summary workbooks, all digital photos, and the annotated PowerPoint presentation. One CD will be transmitted officially to the NASA project office and the other CD will also be transmitted officially to the Customer.

Table 5. MDCA test run log.

Test run log of acoustic emissions test of MDCA ATL-09-04.
All testing took place on Monday 6/7/04.
ATL control room and test chamber HVAC off during all testing. Building 333 Annex HVAC on.

Test Run Number	Start Time	Filename	Comments
	8:10 AM	Calibration of all microphones.	
MDCA AP installed in test chamber.			
	10:15 AM	Completed aural survey of MDCA AP.	No data was collected.
MDCA CIA installed into test chamber.			
1	1:55 PM	MDCA Amb1, Sou-Norm Repeat 01_ATL.xls	Acquired new ambient (Amb1). LD acquired microphone positions #1 & #2.
2	2:20 PM	MDCA Amb1, Sou-Norm Repeat 02_ATL.xls	Did not acquire a new ambient. LD acquired microphone positions #1 & #2.
3	2:45 PM	MDCA Amb1, Sou-Norm Repeat 03_ATL.xls	Did not acquire a new ambient. LD acquired microphone positions #3 & #4.
Rotated the MDCA CIA 180 degrees so it was inverted.			
4	3:15 PM	MDCA Amb2, Sou-Norm Repeat 180 01_ATL.xls	Acquired new ambient (Amb1). LD acquired microphone positions #3 & #4.
5	3:36 PM	MDCA Amb2, Sou-Norm Repeat 180 02_ATL.xls	Did not acquire a new ambient. LD acquired microphone positions #3 & #4.
6	3:50 PM	MDCA Amb2, Sou-Norm Repeat 180 03_ATL.xls	Did not acquire a new ambient. LD acquired microphone positions #1 & #4.
Testing completed. Backed up data to CD.			

Table 6. MDCA channel configuration.

Channel configuration table for ATL-09-04,
acoustic emissions tests of the MDCA, performed on 6/7/04.

Pos #	Mic #	Cable #	Mux Unit #	Mux Chan #	NI Bd #1 4552 Chan #	NI Bd #2 4552 Chan #	NI Bd #3 4551 Chan #	NI Bd #4 4552 Chan #	NI Bd #5 4552 Chan #	NI Bd #6 4552 Chan #	NI Bd #7 4552 Chan #	Microphone Position Description
1	1	1	1	1	1st							Top
2	2	2	1	2	2nd							Front
3	3	3	1	3	3rd							Right
4	4	4	1	4	4th							Back
5	5	5	1	5		1st						Left
6	6	6	1	6		2nd						Bottom
NA	7	7	1	7								Listening Microphone
7	12	LD	1	8		3rd						Ref Mic on top of control room.

Mux #1 = B&K 2822 Multiplexer SN 2088295
Mux #2 = B&K 2822 Multiplexer SN 2088279 (is out for calibration)
= Listening microphone is not recorded.

Appendix A: Test Data

ACOUSTICAL TESTING LABORATORY

NASA Glenn Research Center Acoustical Testing Lab (ATL)

Report Date: 6/7/04, 1:56 PM

Test Information

Test Name	*MDCA Amb1, Sou-Norm Repeat 01*
Test Date/Time	*6/7/04, 1:56 PM*
Test Operator	*James C. Akers, PhD*
Test Description	*MDCA Chamber Insert Assembly*
Comments	*Normal operating cycle, continuously repeating*

Meteorological Information

Temperature (C)	*26.2*
Humidity (%)	*38*
Pressure (KPa)	*99.2*

Measurement Information

All sound pressure data reported herein were obtained at a distance of 0.6 meters from the sides of the DUT.

All data is expressed in decibels(dB) with a reference level of 2*10E-5 Pa.

Greatest Impulsive Indicator = Pos's 1 through 21 : 11.9 dBA

Mic Position Pos 1 Pos 2 Pos 3 Pos 4 Pos 5 Pos 6

Corrected Source SPL Data

Octave Frequency (Hz)	Top SPL (dB)	Front SPL (dB)	Right SPL (dB)	Back SPL (dB)	Left SPL (dB)	Bottom SPL (dB)	Max SPL (dB)	Min SPL (dB)	Avg SPL (dB)
63 Hz	39	36	37	39	38	36	39	36	38
125 Hz	24	25	25	25	24	25	25	24	25
250 Hz	30	28	29	29	29	29	30	28	29
500 Hz	38	39	38	39	40	40	40	38	39
1.00kHz	45	45	46	46	43	45	46	43	45
2.00kHz	42	42	43	43	43	43	43	42	43
4.00kHz	42	41	42	43	42	40	43	40	42
8.00kHz	36	35	36	36	36	34	36	34	36
A-Weighted	49	49	50	50	49	49	50	49	49
Linear	49	49	50	50	49	49	50	49	49

= SPL is within 3dB of exceeding Continuous Noise Limit

= SPL at or exceeds Continuous Noise Limit

Continuous Noise Limits Inside Combustion Chamber

Octave Frequency (Hz)	Limit SPL (dB)	Position4 SPL (dB)
63	57	39
125	51	25
250	60	29
500	60	39
1000	60	46
2000	58	43
4000	57	43
8000	56	36
A-Wtd		50
Linear		50

= Exceeds Continuous Noise Limit

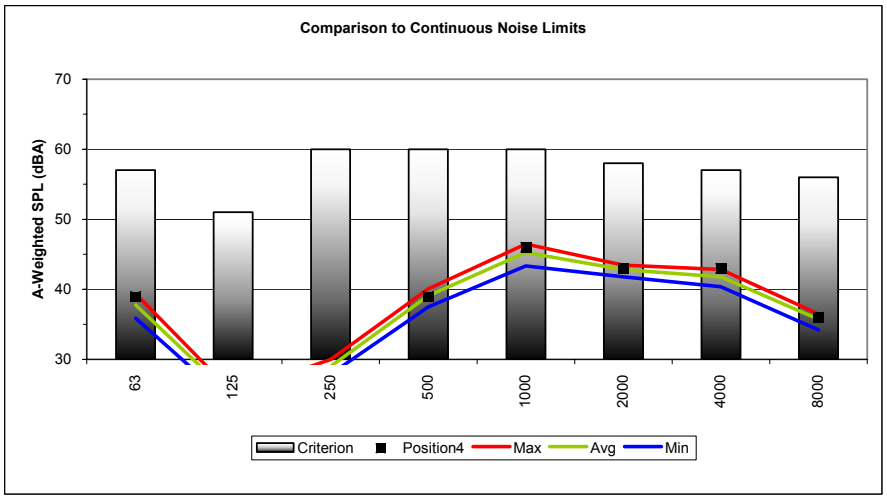

Figure A.1. Test run #1 (filename : MDCA Amb1, Sou-Norm Repeat 01_ATL.xls).

ACOUSTICAL TESTING LABORATORY

NASA Glenn Research Center Acoustical Testing Lab (ATL)

Report Date: 6/7/04, 2:17 PM

Test Information

Test Name	*MDCA Amb1, Sou-Norm Repeat 02*
Test Date/Time	*6/7/04, 2:17 PM*
Test Operator	*James C. Akers, PhD*
Test Description	*MDCA Chamber Insert Assembly*
Comments	*Normal operating cycle, continuously repeating*

Meteorological Information

Temperature (C)	*26.4*
Humidity (%)	*37*
Pressure (KPa)	*99.2*

Measurement Information

All sound pressure data reported herein were obtained at a distance of 0.6 meters from the sides of the DUT.

All data is expressed in decibels(dB) with a reference level of 2*10E-5 Pa.

Greatest Impulsive Indicator = Pos's 1 through 21 : 13.8 dBA

Mic Position Pos 1 Pos 2 Pos 3 Pos 4 Pos 5 Pos 6

Corrected Source SPL Data

Octave Frequency (Hz)	Top SPL (dB)	Front SPL (dB)	Right SPL (dB)	Back SPL (dB)	Left SPL (dB)	Bottom SPL (dB)	Max SPL (dB)	Min SPL (dB)	Avg SPL (dB)
63 Hz	40	37	38	40	39	36	40	36	38
125 Hz	23	25	24	24	24	23	25	23	24
250 Hz	30	28	28	28	29	29	30	28	29
500 Hz	37	39	37	39	39	40	40	37	38
1.00kHz	45	45	46	47	44	47	47	44	46
2.00kHz	43	42	44	43	44	46	46	42	44
4.00kHz	44	42	44	45	43	42	45	42	44
8.00kHz	35	35	36	36	35	33	36	33	35
A-Weighted	50	49	51	51	50	51	51	49	50
Linear	50	49	50	51	50	51	51	49	50

= SPL is within 3dB of exceeding Continuous Noise Limit

= SPL at or exceeds Continuous Noise Limit

Continuous Noise Limits Inside Combustion Chamber

Octave Frequency (Hz)	Limit SPL (dB)	Position6 SPL (dB)
63	57	36
125	51	23
250	60	29
500	60	40
1000	60	47
2000	58	46
4000	57	42
8000	56	33
A-Wtd		51
Linear		51

= Exceeds Continuous Noise Limit

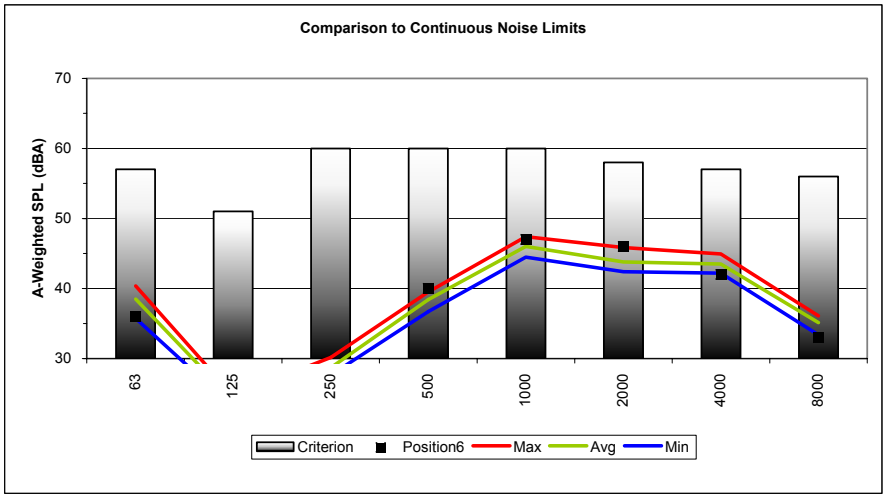

Figure A.2. Test run #2
(filename : MDCA Amb1, Sou-Norm Repeat 02_ATL.xls).

ACOUSTICAL TESTING LABORATORY

NASA Glenn Research Center Acoustical Testing Lab (ATL)

Report Date: 6/7/04, 2:42 PM

Test Information

Test Name	*MDCA Amb1, Sou-Norm Repeat 03*
Test Date/Time	*6/7/04, 2:42 PM*
Test Operator	*James C. Akers, PhD*
Test Description	*MDCA Chamber Insert Assembly*
Comments	*Normal operating cycle, continuously repeating*

Meteorological Information

Temperature (C)	*26.4*
Humidity (%)	*37*
Pressure (KPa)	*99.2*

Measurement Information

All sound pressure data reported herein were obtained at a distance of 0.6 meters from the sides of the DUT.

All data is expressed in decibels(dB) with a reference level of 2*10E-5 Pa.

Greatest Impulsive Indicator = Pos's 1 through 21 : 14.3 dBA

Mic Position Pos 1 Pos 2 Pos 3 Pos 4 Pos 5 Pos 6

Corrected Source SPL Data

Octave Frequency (Hz)	Top SPL (dB)	Front SPL (dB)	Right SPL (dB)	Back SPL (dB)	Left SPL (dB)	Bottom SPL (dB)	Max SPL (dB)	Min SPL (dB)	Avg SPL (dB)
63 Hz	40	35	37	39	38	35	40	35	38
125 Hz	23	25	25	25	24	23	25	23	24
250 Hz	30	29	29	29	29	29	30	29	29
500 Hz	42	39	38	40	40	41	42	38	40
1.00kHz	46	47	47	48	46	49	49	46	47
2.00kHz	45	44	45	46	45	48	48	44	46
4.00kHz	45	44	45	47	45	44	47	44	45
8.00kHz	37	38	37	37	36	34	38	34	37
A-Weighted	52	51	52	53	51	53	53	51	52
Linear	52	51	51	53	51	53	53	51	52

= SPL is within 3dB of exceeding Continuous Noise Limit

= SPL at or exceeds Continuous Noise Limit

Continuous Noise Limits
Inside Combustion Chamber

Octave Frequency (Hz)	Limit SPL (dB)	Position6 SPL (dB)
63	57	35
125	51	23
250	60	29
500	60	41
1000	60	49
2000	58	48
4000	57	44
8000	56	34
A-Wtd		53
Linear		53

= Exceeds Continuous Noise Limit

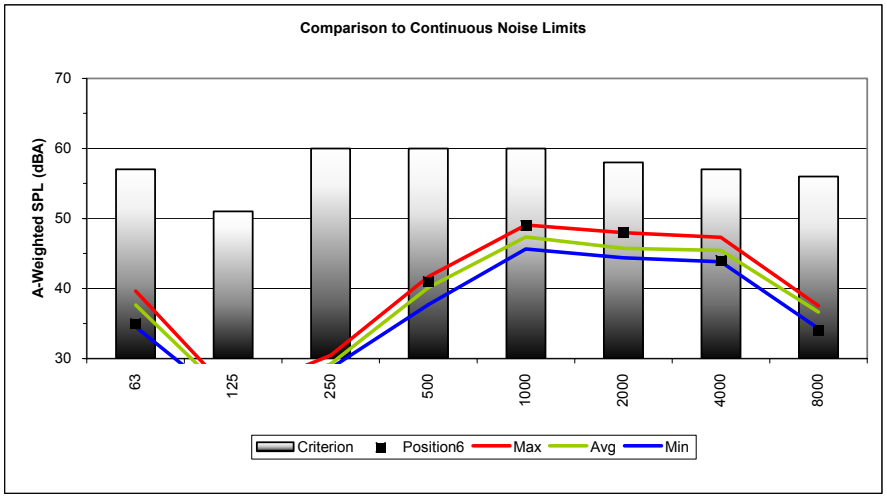

Figure A.3. Test run #3
(filename : MDCA Amb1, Sou-Norm Repeat 01_ATL.xls).

ACOUSTICAL TESTING LABORATORY

NASA Glenn Research Center Acoustical Testing Lab (ATL)

Report Date: 6/7/04, 3:03 PM

Test Information

Test Name	*MDCA Amb2, Sou-Norm Repeat 180 01*
Test Date/Time	*6/7/04, 3:03 PM*
Test Operator	*James C. Akers, PhD*
Test Description	*MDCA Chamber Insert Assembly*
Comments	*Normal operating cycle, continuously repeating, rotated 180 degrees (ie upside down)*

Meteorological Information

Temperature (C)	*26.9*
Humidity (%)	*36*
Pressure (KPa)	*99.2*

Measurement Information

All sound pressure data reported herein were obtained at a distance of 0.6 meters from the sides of the DUT.

All data is expressed in decibels(dB) with a reference level of 2*10E-5 Pa.

Greatest Impulsive Indicator = Pos's 1 through 21 : 13.8 dBA

Mic Position Pos 1 Pos 2 Pos 3 Pos 4 Pos 5 Pos 6

Corrected Source SPL Data

Octave Frequency (Hz)	Top SPL (dB)	Front SPL (dB)	Right SPL (dB)	Back SPL (dB)	Left SPL (dB)	Bottom SPL (dB)	Max SPL (dB)	Min SPL (dB)	Avg SPL (dB)
63 Hz	39	35	36	38	37	35	39	35	37
125 Hz	23	24	24	24	24	23	24	23	24
250 Hz	28	25	26	24	26	30	30	24	27
500 Hz	43	38	36	37	34	40	43	34	39
1.00kHz	48	44	43	45	45	38	48	38	45
2.00kHz	47	41	42	43	42	41	47	41	43
4.00kHz	44	42	42	44	42	43	44	42	43
8.00kHz	35	34	35	35	34	35	35	34	35
A-Weighted	52	48	48	50	49	47	52	47	49
Linear	52	48	48	50	49	47	52	47	49

= SPL is within 3dB of exceeding Continuous Noise Limit

= SPL at or exceeds Continuous Noise Limit

Continuous Noise Limits
Inside Combustion Chamber

Octave Frequency (Hz)	Limit SPL (dB)	Position1 SPL (dB)
63	57	39
125	51	23
250	60	28
500	60	43
1000	60	48
2000	58	47
4000	57	44
8000	56	35
A-Wtd		52
Linear		52

= Exceeds Continuous Noise Limit

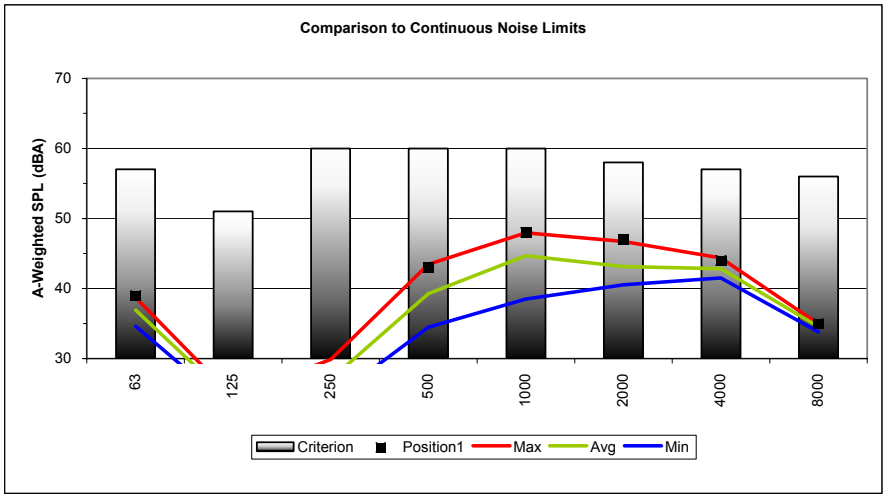

Figure A.4. Test run #4- MDCA CIA inverted (filename : MDCA Amb2, Sou-Norm Repeat 180 01_ATL.xls).

ACOUSTICAL TESTING LABORATORY

NASA Glenn Research Center Acoustical Testing Lab (ATL)

Report Date: 6/7/04, 3:35 PM

Test Information

Test Name	*MDCA Amb2, Sou-Norm Repeat 180 02*
Test Date/Time	*6/7/04, 3:35 PM*
Test Operator	*James C. Akers, PhD*
Test Description	*MDCA Chamber Insert Assembly*
Comments	*Normal operating cycle, continuously repeating, rotated 180 degrees (ie upside down)*

Meteorological Information

Temperature (C)	*27.2*
Humidity (%)	*36*
Pressure (KPa)	*99.1*

Measurement Information

All sound pressure data reported herein were obtained at a distance of 0.6 meters from the sides of the DUT.

All data is expressed in decibels(dB) with a reference level of 2*10E-5 Pa.

Greatest Impulsive Indicator = Pos's 1 through 21 : 13.9 dBA

Mic Position Pos 1 Pos 2 Pos 3 Pos 4 Pos 5 Pos 6

Corrected Source SPL Data

Octave Frequency (Hz)	Top SPL (dB)	Front SPL (dB)	Right SPL (dB)	Back SPL (dB)	Left SPL (dB)	Bottom SPL (dB)	Max SPL (dB)	Min SPL (dB)	Avg SPL (dB)
63 Hz	40	36	38	39	38	36	40	36	38
125 Hz	23	25	24	24	24	23	25	23	24
250 Hz	29	26	27	26	28	30	30	26	28
500 Hz	44	37	36	38	35	42	44	35	40
1.00kHz	48	45	43	46	46	39	48	39	45
2.00kHz	46	41	43	44	43	41	46	41	43
4.00kHz	44	43	42	45	43	43	45	42	44
8.00kHz	36	34	36	36	35	36	36	34	35
A-Weighted	53	49	49	51	50	48	53	48	50
Linear	53	49	48	51	50	48	53	48	50

= SPL is within 3dB of exceeding Continuous Noise Limit

= SPL at or exceeds Continuous Noise Limit

Continuous Noise Limits
Inside Combustion Chamber

Octave Frequency (Hz)	Limit SPL (dB)	Position1 SPL (dB)
63	57	40
125	51	23
250	60	29
500	60	44
1000	60	48
2000	58	46
4000	57	44
8000	56	36
A-Wtd		53
Linear		53

= Exceeds Continuous Noise Limit

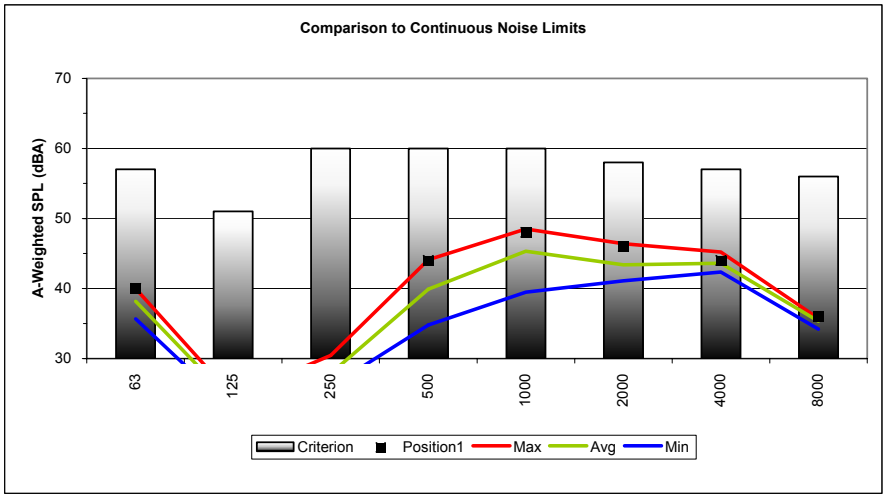

Figure A.5. Test run #5- MDCA CIA inverted (filename : MDCA Amb2, Sou-Norm Repeat 180 02_ATL.xls).

ACOUSTICAL TESTING LABORATORY

NASA Glenn Research Center Acoustical Testing Lab (ATL)

Report Date: 6/7/04, 3:48 PM

Test Information

Test Name	*MDCA Amb2, Sou-Norm Repeat 180 03*
Test Date/Time	*6/7/04, 3:48 PM*
Test Operator	*James C. Akers, PhD*
Test Description	*MDCA Chamber Insert Assembly*
Comments	*Normal operating cycle, continuously repeating, rotated 180 degrees (ie upside down)*

Meteorological Information

Temperature (C)	*27.2*
Humidity (%)	*36*
Pressure (KPa)	*99.1*

Measurement Information

All sound pressure data reported herein were obtained at a distance of 0.6 meters from the sides of the DUT.

All data is expressed in decibels(dB) with a reference level of 2*10E-5 Pa.

Greatest Impulsive Indicator = Pos's 1 through 21 : 13.9 dBA

Mic Position Pos 1 Pos 2 Pos 3 Pos 4 Pos 5 Pos 6

Corrected Source SPL Data

Octave Frequency (Hz)	Top SPL (dB)	Front SPL (dB)	Right SPL (dB)	Back SPL (dB)	Left SPL (dB)	Bottom SPL (dB)	Max SPL (dB)	Min SPL (dB)	Avg SPL (dB)
63 Hz	41	38	39	41	40	37	41	37	40
125 Hz	25	26	26	26	26	24	26	24	26
250 Hz	29	26	27	26	28	31	31	26	28
500 Hz	43	38	36	38	35	41	43	35	39
1.00kHz	47	44	43	45	45	38	47	38	44
2.00kHz	46	41	42	43	43	41	46	41	43
4.00kHz	43	42	42	45	43	43	45	42	43
8.00kHz	35	34	35	35	35	35	35	34	35
A-Weighted	52	48	48	50	49	48	52	48	49
Linear	52	48	48	50	49	48	52	48	50

= SPL is within 3dB of exceeding Continuous Noise Limit

= SPL at or exceeds Continuous Noise Limit

Continuous Noise Limits
Inside Combustion Chamber

Octave Frequency (Hz)	Limit SPL (dB)	Position1 SPL (dB)
63	57	41
125	51	25
250	60	29
500	60	43
1000	60	47
2000	58	46
4000	57	43
8000	56	35
A-Wtd		52
Linear		52

= Exceeds Continuous Noise Limit

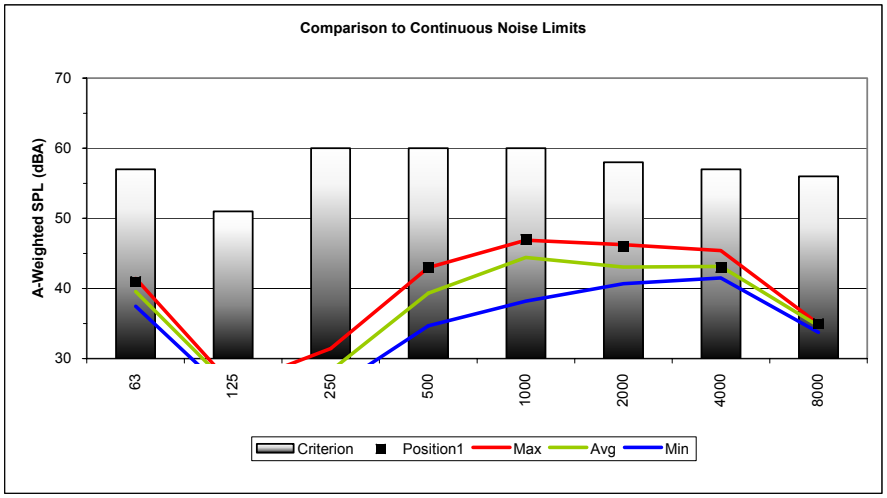

Figure A.6. Test run #6- MDCA CIA inverted (filename : MDCA Amb2, Sou-Norm Repeat 180 02_ATL.xls).

ACOUSTICAL TESTING LABORATORY

Table A.1. Sound pressure levels at each microphone location for all test runs (filename : MDCA Summary Analysis.xls).

Test Run # Octave Frequency (Hz)	1 Top SPL (dB)	2 Top SPL (dB)	3 Top SPL (dB)	4 Top SPL (dB)	5 Top SPL (dB)	6 Top SPL (dB)	1 Front SPL (dB)	2 Front SPL (dB)	3 Front SPL (dB)	4 Front SPL (dB)	5 Front SPL (dB)	6 Front SPL (dB)	1 Right SPL (dB)	2 Right SPL (dB)	3 Right SPL (dB)	4 Right SPL (dB)	5 Right SPL (dB)
63 Hz	39	40	**40**	35	36	37	36	37	**35**	35	36	38	37	38	**37**	37	38
125 Hz	24	23	**23**	23	23	24	25	25	**25**	24	25	26	25	24	**25**	24	24
250 Hz	30	30	**30**	30	30	31	28	28	**29**	25	26	26	29	28	**29**	26	28
500 Hz	38	37	**42**	40	42	41	39	39	**39**	38	37	38	38	37	**38**	34	35
1.00kHz	45	45	**46**	38	39	38	45	45	**47**	44	45	44	46	46	**47**	45	46
2.00kHz	42	43	**45**	41	41	41	42	42	**44**	41	41	41	43	44	**45**	42	43
4.00kHz	42	44	**45**	43	43	43	41	42	**44**	42	43	42	42	44	**45**	42	43
8.00kHz	36	35	**37**	35	36	35	35	35	**38**	34	34	34	36	36	**37**	34	35
A-Weighted	49	50	**52**	47	48	48	49	49	**51**	48	49	48	50	51	**52**	49	50
Linear	49	50	**52**	47	48	48	49	49	**51**	48	49	48	50	50	**51**	49	50

= Measurement may be partially blocked by the CIA cradle test fixture.
Test runs #4 - #6 the CIA is inverted (I.e. upside down).
= Highest A-wtd sound level for that side for all test runs.

Test Run # Octave Frequency (Hz)	1 Back SPL (dB)	2 Back SPL (dB)	3 Back SPL (dB)	4 Back SPL (dB)	5 Back SPL (dB)	6 Back SPL (dB)	1 Left SPL (dB)	2 Left SPL (dB)	3 Left SPL (dB)	4 Left SPL (dB)	5 Left SPL (dB)	6 Left SPL (dB)	1 Bottom SPL (dB)	2 Bottom SPL (dB)	3 Bottom SPL (dB)	4 Bottom SPL (dB)
63 Hz	39	40	**39**	38	39	41	38	39	**38**	36	38	39	36	36	35	39
125 Hz	25	24	**25**	24	24	26	24	24	**24**	24	24	26	25	23	23	23
250 Hz	29	28	**29**	24	26	26	29	29	**29**	26	27	27	29	29	29	28
500 Hz	39	39	**40**	37	38	38	40	39	**40**	36	36	36	40	40	41	43
1.00kHz	46	47	**48**	45	46	45	43	44	**46**	43	43	43	45	47	49	48
2.00kHz	43	43	**46**	43	44	43	43	44	**45**	42	43	42	43	46	48	47
4.00kHz	43	45	**47**	44	45	45	42	43	**45**	42	42	42	40	42	44	44
8.00kHz	36	36	**37**	35	36	35	36	35	**36**	35	36	35	34	33	34	35
A-Weighted	50	51	**53**	50	51	50	49	50	**51**	48	49	48	49	51	53	52
Linear	50	51	**53**	50	51	50	49	50	**51**	48	48	48	49	51	53	52

= Measurement may be partially blocked by the CIA cradle test fixture.
Test runs #4 - #6 the CIA is inverted (I.e. upside down).
= Highest A-wtd sound level for that side for all test runs.

Table A.2. Maximum slow exponential, fast exponential, and impulsive overall A-weighted sound levels (filename : MDCA Summary Analysis.xls).

Test Run #	Mic Pos #	Location	LD Source Max Impulsive A-Wtd (dBA)	LD Source Max Fast Exp A-Wtd (dBA)	LD Source Max Slow Exp A-Wtd (dBA)	LD Source Leq A-Wtd (dBA)	NI Source Leq A-Wtd (dBA)	LD Ambient Background Leq A-Wtd (dBA)	NI Ambient Background Leq A-Wtd (dBA)	Comments
1	1	Top	65	62	54	47	49	19	19	
	2	Front	65	61	54	46	49	18	18	
										The excellent agreement between the NI and LD ambient Leq A-wtd sound levels shows that the LD is functioning properly. LD 2900B and NI SPS both overloaded during data acquisition of source. This overload is the reason for the discrepancy between the NI and LD source Leq A-wtd sound levels. The overload appears to have been detrimental to the LD measurements, but not the NI SPS measurements.
2	1	Top	75	70	62	50	50	NR	NR	
	2	Front	75	70	62	49	50	NR	NR	
										Very good agreement between the NI and LD source Leq A-wtd sound levels. (:-)
3	3	Right	75	70	62	50	52	NR	NR	
	4	Back	77	72	64	51	53	NR	NR	
										The 2 dB between the NI and LD source Leq A-wtd sound levels is probably due to the NI and LD acquiring data at slightly different times.
4*	3	Left	73	69	61	48	48	19	18	
	4	Back	77	72	64	51	50	19	19	
										Very good agreement between the NI and LD source and ambient Leq A-wtd sound levels. (:-)
5*	3	Left	74	70	61	49	49	NR	NR	
	4	Back	77	72	63	51	51	NR	NR	
										Very good agreement between the NI and LD source Leq A-wtd sound levels. (:-)
6*	1	Bottom	78	74	66	52	52	NR	NR	
	4	Back	77	72	64	51	51	NR	NR	
										Very good agreement between the NI and LD source Leq A-wtd sound levels. (:-)
Max over all test runs			78	74	66	52	53	19	19	

Notes: LD = Data collected independently with a LD 2900B analyzer operated in SLM mode.
NI = Data collected with the NI data acquisition system running NI SPS w MCE software (Leq only).
* = The MDCA CIA was inverted for these test runs, but microphones were not moved. Therefore, pos #1 goes from being on the top side to being on the bottom side, pos #3 goes from being right side to being on the left side, and pos #5 goes from being on the left side to being on the right side.
Pos #2 in front remains in front and pos #4 on the back side remains at the back.